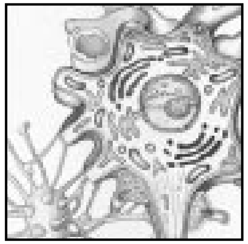
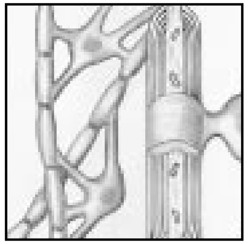
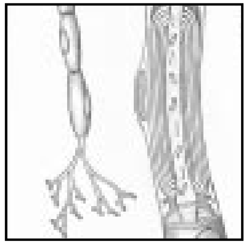
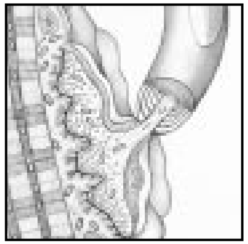
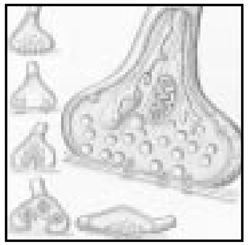






C40

C 40/1
C 40/2
C 40/3
C 40/4
C 40/5

Introduction

Functional anatomy of the nerve cells

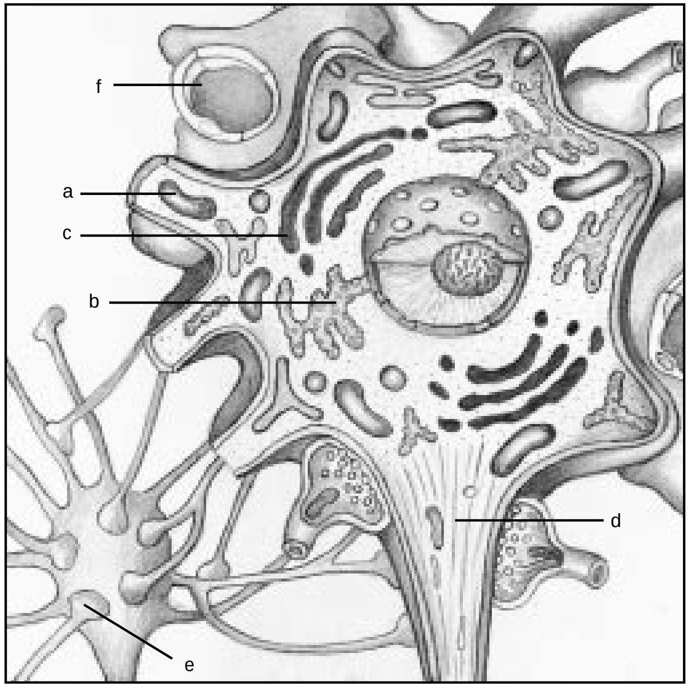
Nerve cells are the smallest independent units of the organs of the nervous system. A distinction is generally made between the central and the peripheral nervous system: the brain (cerebrum and cerebellum) and the spinal cord belong to the central nervous system. The peripheral nervous system consists of all nerve fibres of the periphery (e.g. in the skin, muscles and all visceral organs). A differentiation is made between the consciously (will or senses) accessible or somatic nervous system and the vegetative (autonomic) nervous system which automatically without voluntary access takes over control of the inner organs. The spinal cord uses reflex cycles to mediate between the periphery and the brain as well as to mediate for the vegetative and somatic nervous system.

The nervous system has many tasks ranging from impulse uptake (seeing, hearing, smelling, feeling, etc.) through transmission of impulse or information, information processing and storing to the answering of incoming information with corresponding patterns which result in voluntary movements. This variety also mirrors the shape and function of the individual nerve cells. The individual cell is an extremely varied, multifunctional structure with numerous special shapes. It is so highly specialized that it is not viable alone. It has even given up the ability to regenerate (which is still maintained in the skin cells, for example). This means that a nerve cell cannot be replaced adequately if it dies after the nerve tissue has developed fully. Only the peripheral nerve processes can regenerate at a growth rate of max. 1 mm/day.

The auxiliary cells (glial cells) must help the nerve cells to fulfil their metabolic and transport functions. The nerve cells themselves concentrate entirely on maintaining their extremely complicated structure, the most important factor being the surfaces, i.e. the membranes. This is because the membranes take on the main task of the nerve cell: the change from excitation and non-excitation of the membrane takes place here. This change can be determined by measuring tension (in mV). A differentiation is made between resting and action potential. The entire structure of the nerve cell and the glial cell is based on this function. Thus certain glial cells (astroglia) are specialized in the task of transporting substances from the capillaries (f in Fig. C40/1) in the direction of the nerve cell. Thus nothing uncontrolled comes from the very dense capillaries in the brain and spinal cord to the nerve cell. Other glial cells are specialized in surrounding the nerve cells with insulating shells (oligodendroglia in the central nervous system, C40/2, or Schwann glial cells in the peripheral nervous system, C40/3). Other glial cells surround the terminal cells of the nerve endings in the periphery (teloglia, b in Fig. C40/4).

C40/1

Nerve cell

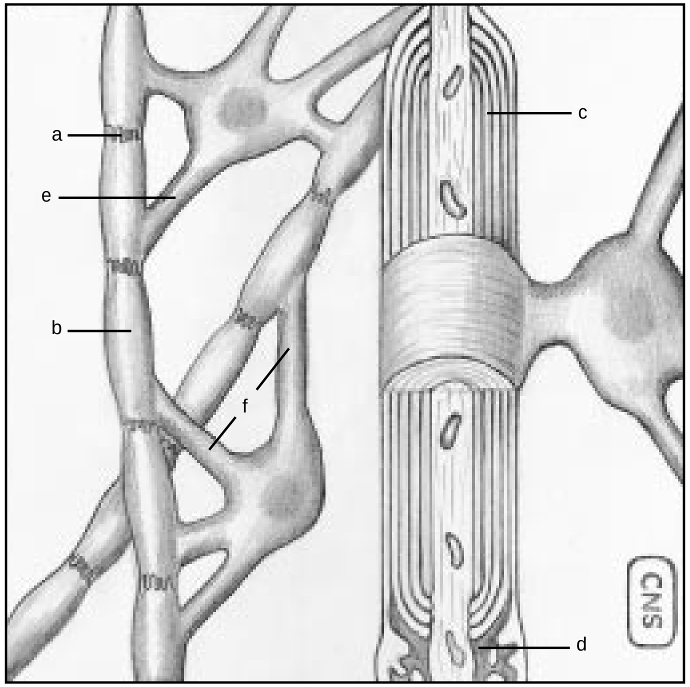


A nerve cell is divided into the central cell mass grouped around the nucleus (perikaryon) and the numerous nerve processes. The nerve processes are divided into dendrites, which transmit information to the perikaryon, and the neurite (only one present). This transmits the information to the next nerve cell.

If the perikaryon is observed (cut open in the figure), numerous characteristics may be recognized which are present in every mammalian cell: mitochondria (a), endoplasmic reticulum (b), Golgi's apparatus (c) and numerous fibrils of the cytoskeleton (d). Golgi's apparatus and the endoplasmic reticulum are particularly marked in the nerve cell as they are both involved in the production and renewal of the enormous membrane surface of the nerve cells. A well-structured fibre network, a subunit of the cell skeleton, may be found in the numerous branches. In addition, special formations of branches, i.e. numerous synapses (e), may be seen on the left-hand side of the figure.

C40/2

Myelin sheath of the central nervous system

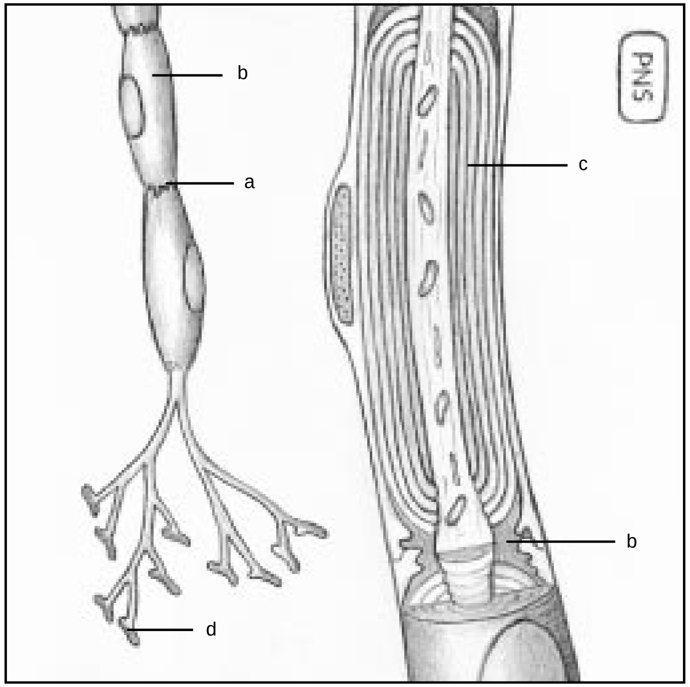


The membrane of the nerve cell is principally responsible for the spreading process of the nerve impulse. In addition, there is a connection between the thickness of the nerve process and the transmission speed. The thicker the nerve process, the greater the transmission speed. Without appropriate auxiliary cells (specialized glial cells), impulse transmission is continuous (only occurs in invertebrates or in thin fibres of the vegetative nervous system of vertebrates). In order to increase the transmission speed, nerve fibres with myelin sheaths form which are interrupted by what are known as constriction rings (a) (nodes of Ranvier) at intervals of 1 mm to 3 mm. This causes transmission of impulses to be accelerated considerably, without the diameter of the nerve process having to be increased greatly. The impulse jumps from constriction ring to constriction ring and transmission becomes faster. Insulation between the individual constriction rings (b) occurs using fat-containing substances (lipids, myelin, cephalin, phosphatides, lecithin, cerebrosides, etc.). A uniform layer of extremely thin lipid protein lamellae and the membrane of the glial cells (c) occurs. This spiral insulation is interrupted at the constriction rings (d).

In the central nervous system, the oligodendroglia take on the task of insulating the nerve processes. They are also important for the metabolism of the nerve cells. Characteristic for the oligodendroglia is that they can insulate several segments between the constrictions (interannular segments) at the same time (e) due to several star-shaped branches and they can also serve various nerve fibres (f).

C40/3

Glia of the peripheral nerve cells

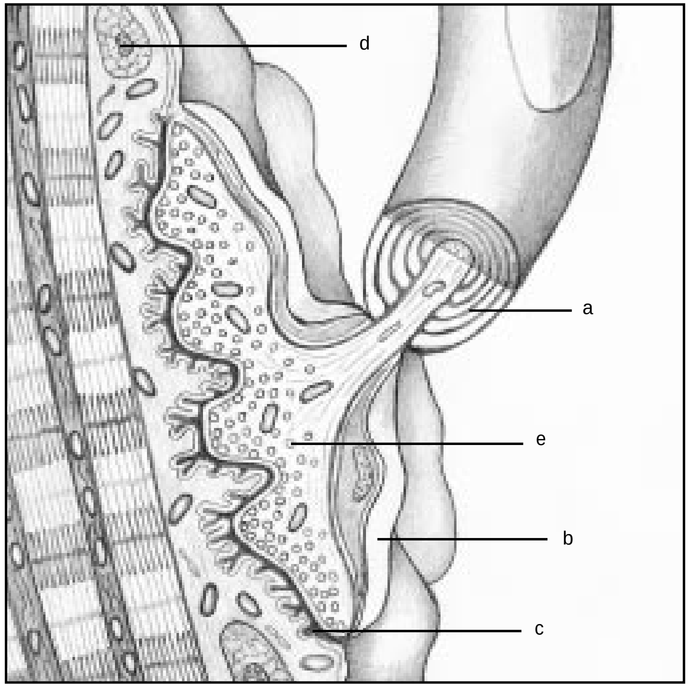


In the same manner as the oligodendroglia in the central nervous system, the Schwann cells in the peripheral nervous system form the myelin sheath to insulate the nerve process. In this case too, constrictions (a) and interannular segments (b) form. Characteristic for the glial cells of the peripheral nervous system is that each cell supplies only one interannular segment. Thus a change to another glial cell takes place during constriction. The structure made of myelin sheaths and membranes of the glial cells (c) is the same as that of the oligodendroglial cell. The change from an insulated proportion to a more or less free membrane means that the impulse jumps from constriction to constriction (saltatory impulse transmission). This causes a considerable increase in impulse transmission.

The subdivision of the nerve processes at the end of the peripheral nerves may be extremely varied. They can end freely in another tissue (free nerve endings) (d). They are often integrated into complicated endings of the end glia (teloglia), such as tactile corpuscles or other complicated sensory organs.

C40/4

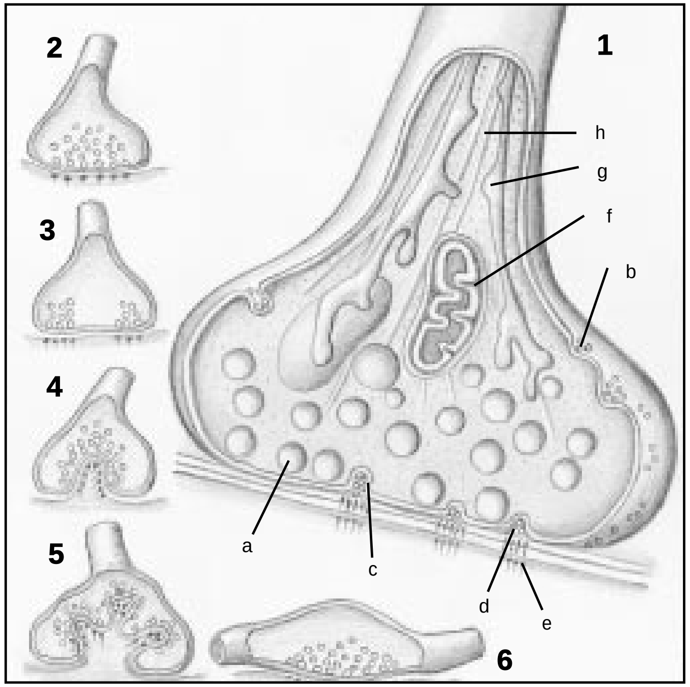
Motor end plate



In the motor end plate, a special type of synapsis, impulses are transmitted from a nerve cell to a striated skeletal muscle fibre. Shortly before the motor end plate, the nerve process loses its myelin sheath (a) and is only sheathed by the glial cell itself (teloglia, b). The terminal section of the nerve cell widens at the contact point to the muscle fibre and reforms numerous synaptic vesicles, mitochondria and granula of various types. The terminal branches of the nerve process accumulate in the cell membrane, the muscle fibre (postsynaptic membrane) close to it. The membrane of the muscle cell forms an intensive folding apparatus towards the surface enlargement (c). A striking amount of nuclei of the muscle cell (d) are found in the cytoplasma of the muscle fibres, causing the end plate to bulge slightly. This leads to a huge contact point at which a single nerve impulse can trigger excitation of the muscle fibres. The synaptic vesicles (e) in the nerve endings contain the transmitter acetylcholine which docks at receptors of the postsynaptic membrane according to the mechanism in the synapses and from there causes renewed excitation of the muscle fibres.

C40/5

Synapse



A synapse is a contact structure specifically serving to transmit impulses and used for one nerve cell to "innervate" another (1). There are electrical and chemical synapses. Electrical synapses directly transmit the impulse to a neighbouring cell membrane (very rare in the human nervous system, between the hair cells of the inner ear or between the sensory cells of the retina) (Figures). In the case of chemical synapses, the nerve cell forms button-like swellings at its terminal branches (boutons, Fig. C40/1, e) which are specialized in information transfer. In the case of chemical synapses, the impulse is transmitted indirectly via certain chemical substances. The impulse, which is transmitted from the nerve cell along the cell membrane to the button-like swelling, is converted to a time-correlated release of transmitting substances which are encapsulated in vesicular structures (synaptic vesicles) (a).

The nerve impulse, depolarization, temporarily opens tension-controlled calcium channels in the membrane which are in front of the actual transmission site. As calcium concentrations are always 1000 times greater outside than inside the cell, calcium flows into the nerve cell and the increasing calcium concentration triggers the release of vesicles with transmitting substances. The vesicles first fuse with the presynaptic membrane (c), the transmitters being released in the synaptic cleft (d) and finally taken up by the postsynaptic membrane. The transmitting substances bind to specific receptors (e) and open coupled channels which depolarize the membrane of the neighbouring cells in a limited area by the inflow of sodium ions. A chain reaction opens further neighbouring channels and a self-spreading depolarization occurs which spreads to the entire plasma membrane of the following cell.

C40 / 5

Synapse

After depolarization the transmitter substances either undergo degradation or they will be taken up again by the presynaptic button-like swelling (b).

As a synapse must often conduct this process in a very short time (several times per second), it is a site of high metabolic activity. Thus mitochondria (f) are found here, which display a high energy metabolism, as well as branches of the endoplasmic reticulum (g), a sign of high substance metabolism. The filaments of the cytoskeleton in the synapse (neurofilaments) (h) are guide structures for axonal transport which is used as a route for transmitters and membrane components from the perikaryon to the synapse.

A distinction is made between two types of synapses (Gray I and II), depending on the type of synaptic vesicles and the thickening of the presynaptic and postsynaptic membrane. Gray I synapses have light, round vesicles, a cleft measuring 30 nm in width and the postsynaptic membrane is thicker than the presynaptic one (2). Gray II synapses have a cleft measuring 20 nm in width and have narrow postsynaptic membrane thickening, several active fields often being located beside each other (3). Gray I type synapses are regarded as excitatory synapses, Gray II type as inhibitory synapses. Inhibitory synapses suppress the excitation readiness of a subsequent cell.

In addition to these basic types, there are special forms based on shape and fine differentiation of function: e.g. synapses with synaptic cords (4), complex synapses with cords (5). Nerve processes can form synapses when passing by ("en passant") (6). They either have the typical presynaptic and postsynaptic membranes or they have free endings (in the vegetative nervous system). They are no longer surrounded by glial cells on their outer end and give the transmitters to neighbouring cells over greater distances ("à distance"). The motor end plate is also a special form of synapse.

Questions

1. How many synapses may end on one nerve cell in the central nervous system?
Up to 20,000

2. How many nerve cells are there in the cerebrum and cerebellum?
Approx. 10^{12} - 10^{14}

3. Which nerve cells are involved in the proprioceptive reflex?
1) Cells whose process is in the muscular spindles (sensor) = pseudounipolar spinal ganglia
2) Cells which innervate the muscle = multipolar cells in the anterior horn of the spinal cord

4. Which 2 cell types are found in nerve tissue?
Nerves (neurons) and glial cells

5. Where does a) impulse uptake (afference) and b) impulse transmission (efference) take place?
a) Dendrite
b) Neurite

6. What is the mechanism called via which substances are transported from the perikaryon to the periphery along the cytoskeletal fibres?
Axonal transport

7. What is the name of the impulse transmission site from one nerve cell to the next?
Synapse

8. Which "trick" does nature use to increase the speed of nerve transmission?
Constriction rings and insulated (myelinized) sections

9. What is the term used to describe the spread of the impulse in myelinized nerves?
Saltatory impulse transmission

10. How many cerebral nerves form the peripheral nervous system of the head?
12

11. Which spinal cord segments supply the brachial plexus?
C_5 - Th_1

12. Which spinal cord segments supply the upper thigh, lower thigh and foot?
L_5 - S_3

13. Which basal ganglia belong to the telencephalon?
Caudate nucleus, putamen and pallidum

14. How is information coded in the nervous system?
As an impulse sequence

15. What is excitation of the nerve cell membrane called?
Action potential

16. Which transmitter present in the pathways from the substantia nigra to the corpus striatum is absent in Parkinson's disease?
Dopamine

17. What is the name of the receptor organ in the cochlear duct of the inner ear?
Organ of Corti

18. How is the eye-visual cortex connection produced?
Optic nerve, optic chiasma, optic tract, lateral geniculate body, optic radiation

19. Which functions does the hippocampus have?
Learning and memory